Urban Flood Management in Metropolitan Cities of India

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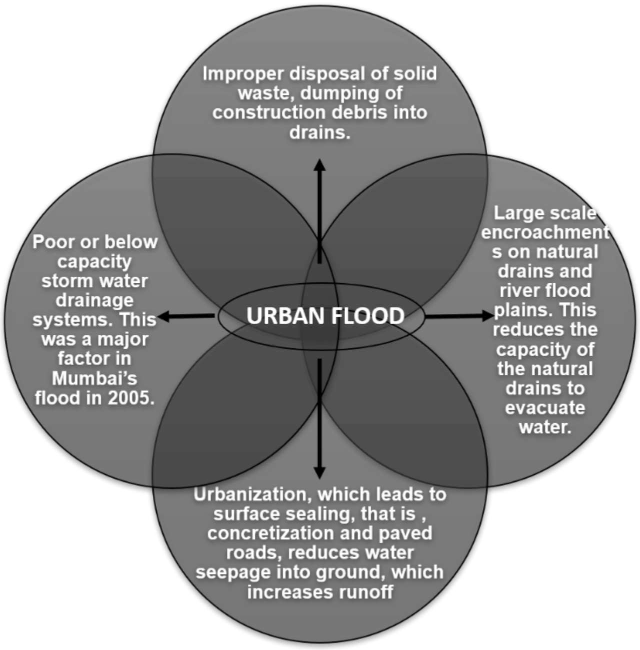
Abstract: To have a sustainable development, it is essential to incorporate the idea of resilience into the planning of our cities in the fast-changing world of increased urbanization, vulnerability, and resilience. A system's vulnerability is its susceptibility to, and inability to withstand, the negative consequences of climate change. A system, community, or society's resilience is its capacity to withstand, absorb, adapt to, and recover from the consequences of risks. In India, floods rank among the deadliest natural calamities. Urban flooding poses a serious risk to Indian cities. Planning a city without a robust resilience strategy to cope from disasters is equivalent to wasting resources and putting people, infrastructure, assets, and economy at risk. When rivers and streams overflow their banks and flood the nearby low-lying areas, known as the natural floodplains, it results in fluvial flooding. Pluvial flooding is a disastrous occurrence that occurs when rainfall exceeds the capacity of drainage systems, submerging land, or property in a developed environment, especially in regions with higher population densities (like cities).

Keywords: Spatial planning, Sponge cities, Pluvial flooding, Fluvial Flooding, Flood Vulnerability Index

Introduction

Urban flooding is the accumulation of floods caused by storm water entering a drainage system that is unable to remove the water or allow it to seep into the ground. Flooding is one of the most frequent natural disasters. Floods are affecting an increasing number of people and causing significant damage to both the natural environment and urban regions. Although it is accepted that floods cannot be avoided, there are things that may be done to decrease the harm and vulnerability of communities who are in risk. auxiliary When rainfall surpasses the ability of drainage systems, flooding is a disastrous occurrence that submerges land or property in a developed environment, particularly in areas with higher people concentrations (like cities). The need to alter the approach to flood risk management led to the development of integrated flood risk management. The emphasis moved to community vulnerability from traditional flood risk management. Cities are seeing an increase in the frequency of disruptive floods. One of the most frequent natural catastrophes in the globe, urban flooding poses a major threat to many parts of the planet. In addition to having negative socioeconomic repercussions, urban floods have the potential to demolish urban infrastructure and disrupt municipal services including communication, sewerage, transit, and electricity delivery. Since the 1990s, urban flooding has become the most common and persistent natural catastrophe with disastrous impacts on a worldwide scale. Indian cities are experiencing more and more flooding due to a combination of natural and man-made factors, with man-made factors having a greater impact. A few of the floods that have occurred are those in 2005 Mumbai, 2007 Kolkata, 2009 Delhi, 2015 Bangalore, and 2020 Hyderabad. most noteworthy incidents of flooding in cities. On average, floods cause 1600 fatalities each year and damage to homes, farms, and public services valued at Rs. 1805 crores. More often than once every five years, there are significant floods. Jal Shakti Abhiyan, Atal Bhujbal Yojna, Amrit Sarovar are Some Government Initiatives to Curtail Urban Flooding. These all missions come under SDG- 6(Clean water and Sanitation). Focus has also turned to Climate Resilience that is SDG – 13.

Figure 1 Causes of Urban Flooding



Source- Author

Need of the Study

Research suggests that inadequate planning and urban management may result in yearly losses for Indian cities ranging from USD 2.6 to USD 13 billion. Town planners have faced challenges when it comes to disaster resilience and management in urban settings. Making our cities robust to flood catastrophes and tragedies can help to reduce the massive loss of lives, property, economy, and society. Resilience must be ingrained in the planning and development of a city's infrastructure from the very beginning because disasters typically strike quickly, leaving little time for preparation or quick mitigation measures. As a result, resilience must be incorporated into the design process from the very beginning to ensure that the finished product is resilient to shocks and stresses. To have a comprehensive grasp of the potential and problems related to flood control, it is imperative to study urban flood management in India. It makes it possible to create well-informed plans and policies that support development and planning of space. Inadequate regulations and policies pertaining to infrastructure can cause problems for flood control.

Impact of Floods in India

235 floods struck India between 1980 and 2017, affecting 1.93 billion people and resulting in 126,286 fatalities. 1.0% Floods might cause a 2.7% decline in economic growth. Over 50% of climate-related disasters in India are caused by flooding. $54.63 billion in damages between 1990 and 2019 were inflicted. 20%, or 40 mills out of 328.5 mills. Floods frequently occur on hectares of land.

Table 1 Impact of Floods in India

State	Year	Reason	Death	Population affected	Property damage
Assam	2012	Heavy Rainfall	20	Over 2 million	---
Uttarkhand	2013	Monson flood	4100	Nearly 4000 Villages	21141 Houses& 5000 Cr Loss in Infrasctrure
Delhi	2013	Heavy Rainfall And Dams Gate opening	29	130 villages and 25 Urban Colonies	15-20 Cr
West Bengal	2015	Cyclone and Rainfall	48	10,000 Villages and 12 Districts	38000 Houses
Uttar Pradesh	2017	Long Term Rainfall	10	2 Million	1182 Buildings
Kerala	2018	Heavy Rainfall	339	5.4million	75,857 Cattles, 6.42 lakh houses
Bihar	2019	Heavy Rainfall	116	10 Million	---
Hyderabad	2020	Drepression and Flash Floods	81	1.08 Million	20,800 Houses
Banglore	2022	Heavy Rainfall	119	5 Lac	1161 Cattles, 35605 houses &225 Cr loss

Source- Author

Table 2 Vulnerable communities to flood

Vulnerable Communities to Floods	
Gender Basis	**Race**
• Women's & Girls (80%), • Men (20%) • Transgender	• Racal minorities • Ethnic minorities
Socio-economic status	**Marginalized communities**
Informal workers ▪ Farmers ▪ Ranchers ▪ Slum dwellers	• Prisoners • The disabled • Immigrants • LGBTQ +
Age basis	**Region**
<17 years & >70 years	• Fisherman • Boatman • Beach vendors

Source- Author

Disaster Management Framework for Flooding

Table 3 Government Initiatives to Curtail Flooding

Jal Shakti Abhiyan
Amrit Sarovar Mission
Model Building bye Laws (2016)
Atal Bhujbal Yojna
Amrut 2.0
National water Policy (2002)
SOPs on Urban Flooding by MOHUA.

Source- NDMA (GOI), 2008

Table 4 Structural and Non Structural Measures

Regulating land use in flood plains to minimize flood damage.
Mitigating distress and providing immediate relief in flood-prone areas through measures like raised platforms for flood shelters and elevated public utility installations.
Each government department and agency should prepare its own plans to manage floods effectively.
Managing water resources at the basin or watershed for comprehensive management.
Real-time discharge and rainfall data are essential for formulating accurate forecasts and warnings.

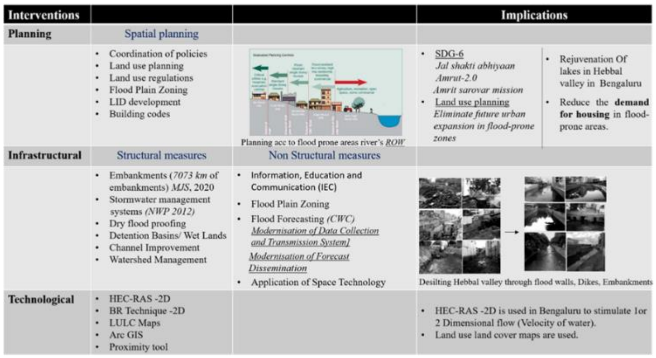
Source- NDMA (GOI), 2008

Table 5 Institutional Framework for Flooding in India

Water Sensitive Urban Design in Australia
Low Impact Development/ Green Infrastructure in UK
Sustainable Urban Drainage systems in UK.
Decentralized Underground Rainwater /Stormwater Management in Germany
Sound Water Cycle in National Planning in Japan.
Smart Watergy City, U Eco City in South Korea.
Sponge Cities In China.

Source- NDMA (GOI), 2008

Figure 2 Role of Urban Planners in Flood Management



Source- Author

Global Responses to Urban Floods

Table 6 Global Response to Urban Floods

Central Government	GFCC, IMD, DOWR
State Government	DDMA, NDMA

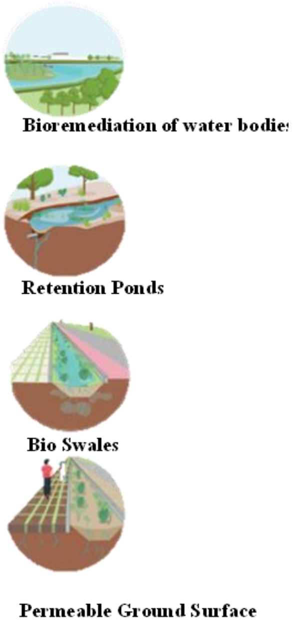
Source- Roger Naylo (Euro News)

Literature study (Interventions)

Nature Based Solutions

To "protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing benefits to biodiversity and human well-being," nature-based solutions, or NBSs, are non-structural interventions. In addition to slowing down the flow of water, NBS measures can assist lessen the effect of floods in the context of urban flooding by redirecting and holding floodwater. NBS contributes to the improvement of recreationally-useful urban areas, the reduction of the heat island effect, and the enhancement of urban biodiversity. NBS is an affordable method of reducing flood damage, and the interventions also improve the quality of the water and soil. Cities may design a suitable combination of NBS actions to optimize gains and minimize expenses. Cities need to establish strategies, rules, and frameworks of this kind to provide a roadmap for enhancing flood resistance. Sponge cities and Blue Green Infrastructure are some of the Solutions. Sponginess is measured covered by 'blue and green infrastructure' compared with the 'grey infrastructure'.

Figure 3 Nature Based Solutions



Source- GFDRR

Figure 4 Planning Based Interventions

Source- GFDRR

Planning Based Interventions

According to studies, inadequate urban planning and administration would likely cost Indian cities between USD 2.6 and USD 13 billion a year. As flood hazards rise, land use and long-term development for flood resilience can be influenced by socioeconomic and geographical vulnerabilities, risk assessment, and a coordinated strategy. To successfully execute flood resilience measures, multi-sectoral and multi-stakeholder collaboration must be ensured through strategic planning. Cities may control floods more effectively with the help of the Ministry of Housing and Urban Affairs' (Mohua) Standard Operating Procedure (SOP) for flood management.

Technological Based Interventions

Advances in technology have led to advancements in flood forecasting and computational flood models. Identifying geographical vulnerabilities and providing guidance for emergency flood management may be achieved by integrating these models with Geographic Information Systems (GIS). The location and depth of flooding may be predicted using hydrodynamic models by utilizing historical data and meteorological forecasts. Flood control centers are specialized facilities that keep track of flood events and water levels in bodies of water, maintain flood mitigation systems, and disseminate early warning systems. Through the collection, analysis, and dissemination of flood-related data, local communities are involved in the community-based early warning system, which also disseminates warning messages. The goal is to provide communities the capacity and authority to conduct disaster management and flood mitigation measures.

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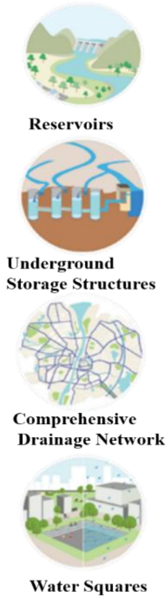
Figure 5 Technological Interventions

Source- GFDRR

Infrastructural Based Interventions

Infrastructure interventions are designed and built structures that transport and store stormwater in addition to serving as flood barriers. Reservoirs, embankments, and levees are a few of the often-utilized structural flood prevention techniques. These actions take up less land while also helping to contain runoff water from susceptible areas. They are a practical way to lessen the effects of floods in places where there is a significant concentration of assets and people. Such interventions can be constructed as multifunctional structures or buildings that provide public spaces and recreational activities in addition to constructing flood resilience. Care must be used while choosing structural measures since, if done incorrectly, they might disrupt the natural ecosystem and alter environmental patterns.

Figure 6 Infrastructural Interventions

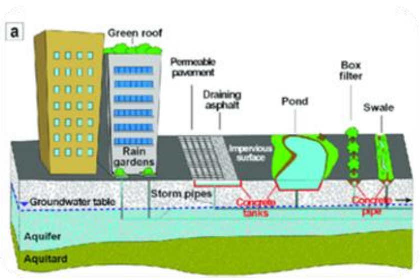


Source- GFDRR

Literature study (Sponge City China)

In essence, a sponge city collects and holds onto surplus stormwater, filters it, and then gradually releases it—just like a sponge. NbS such as wetlands, greenways, parks, rain gardens, green roofs, and bioswales are commonly used in sponge cities. The PRC's heavily urbanized areas face four major water challenges: an excess of water supply, a shortage of water supply, murky water, and pollution. One major idea is to enhance flow capacity and retention by utilizing thoughtfully planned green areas, such as floodplains and gently sloping embankments, to better regulate river floods. Green infrastructure, which is intended to hold and slow down stormwater before it runs into drainage pipes and canals, is used in the event of urban floods.

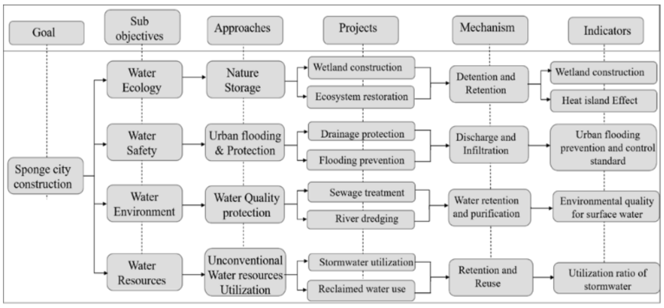
Figure 7 Sponge City



Source- Yong Tian (SC Development)

In accordance with the guidelines, certain measures—like permeable paving, sunken green spaces, biological retention facilities, infiltration, seepage wells, rainwater wetlands, rainwater tanks, conditioning tanks, grass ditches, seepage pipes/drains, vegetation buffer zones, initial rainwater abandonment facilities, and artificial soil infiltration—should be considered and integrated. The standards include defining runoff reduction objectives at the federal, regional, and local levels as well as stormwater and precipitation storage capacity. It is an extremely ambitious national goal to reduce urban runoff by 80%.

Figure 8 Methodology for Designing Sponge City

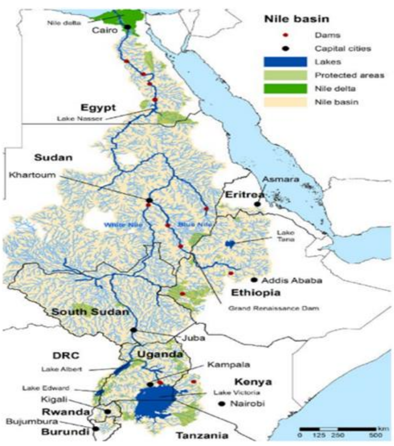


Source- IHE Delft Institute for Water Education

Literature study:Nile River Basin Management

The White Nile, Blue Nile, and Atbara, the Nile's three major tributaries, have seasonal variations that affect the 6825-kilometer-long river. 3,349,000 square kilometers make up its drainage basin. The intensity of the floods has been seen to increase with time, with most of the damage occurring to mud buildings situated downstream of the river.

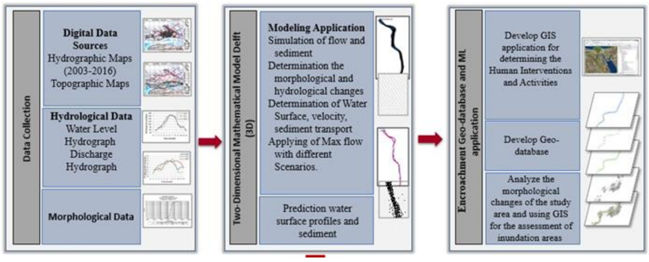
Figure 9 Nile River Basin



Source- IBRD (International bank for Reconstruction and Development)

Data was collected through various sampling methods like Bathymetric data, Flow Velocity Distribution Measurements, Bed material sampling and Hydrological Data. Delft3D is a hydrodynamic model that can be used to simulate water flows, sediment transports, morphology, water quality, and particle tracking.

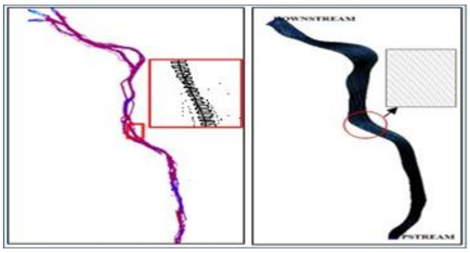
Figure 10 Methodology of Delft 3d Model



Source- Nehla sadak (NWRC), 2022

The grid stretched for 60 km along the shoreline. A fine grid of (100m*160m) was used in the model. The model's calibration and verification depend on the amount and quality of topographic and hydraulic data collected, such as velocity distributions, water-surface elevation, flow rates, and bed roughness.

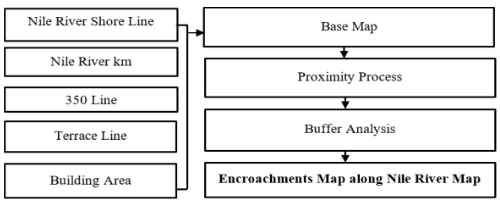
Figure 11 Grid Elements and Bathymetric data



Source- Nehla sadak (NWRC), 2022

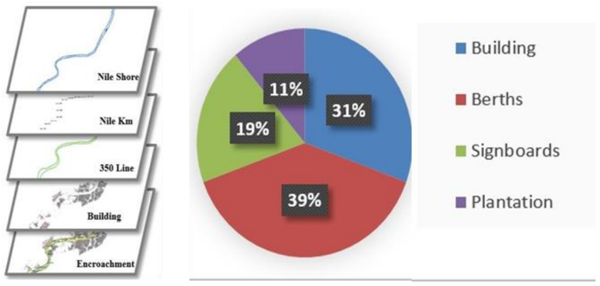
Studying effect of the changes in water levels and Nile River Human Interventions and Activities through Developed Application of GIS.

Figure 12Methodology for Defining Encroachments



Source- Nehla sadak (NWRC), 2022

Figure 13 River Basin Encroachment Classification



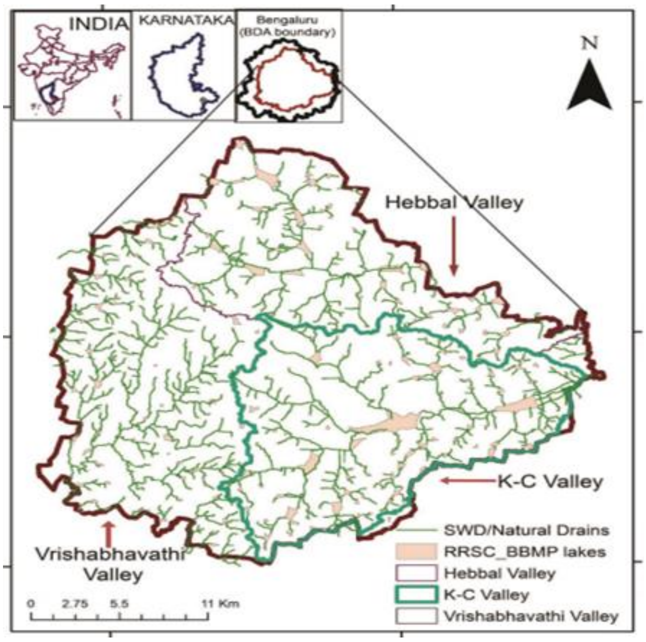
Source- IBRD (International bank for Reconstruction and Development)

Field data collection and analysis is not sufficient to clarify the risks associated with floodplain areas. Uncordial implementation of software data on ground level. Lack of Disaster resilience infrastructure away from the coastal plains, which leads to river encroachments. Mismanagement of Barrage Operational Rules.

Literature study: Flood Model Bengaluru

The city of Bengaluru (urban) has an area of 709 sq.km administered by BBMP within the BDA area of 1245 sq km. The natural terrain of the city has three major outward-draining valleys- Hebbal Valley (NW-E), Koramangala – Challghatta valley (S-NE) and Vrishabhavathi Valley (N-S). Study of the land-use pattern indicates that about 30% of the central part of Bengaluru is impervious, which results in the generation of higher run-off as overland flow during an intense rainfall event. In 2018, a report by Niti Aayog stated that Bengaluru would run out of groundwater by 2020.

Figure 14 3 Valleys of Study area



Source: *IUFM Integrated urban flood management (2011)*

An integrated urban flood model (UFM) for Bengaluru city is being developed by the Indian Institute of Science (IISc), Bengaluru, in collaboration with the

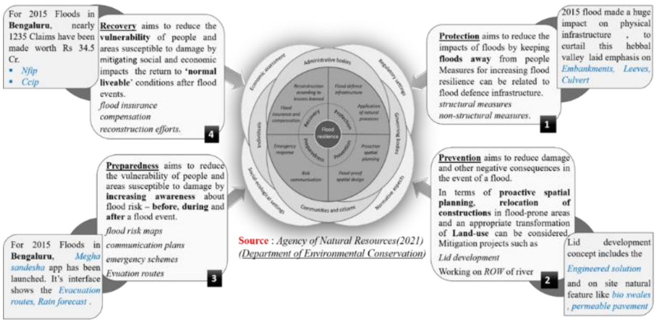
Source- IBRD (International bank for Reconstruction and Development)

Karnataka State Natural Disaster Monitoring Centre (KSNDMC). (BDA) and (BWSSB) as the stakeholders. The UFM flood model has been developed using the storm water management model (SWMM) of the United States Environmental Protection Agency (EPA). SWMM is a dynamic rainfall–run-off simulation model designed specifically for urban regions, and is used to compute the run-off generated from rainfall after accounting for various losses from the system.

Figure 15 Components of Urban Flood Model

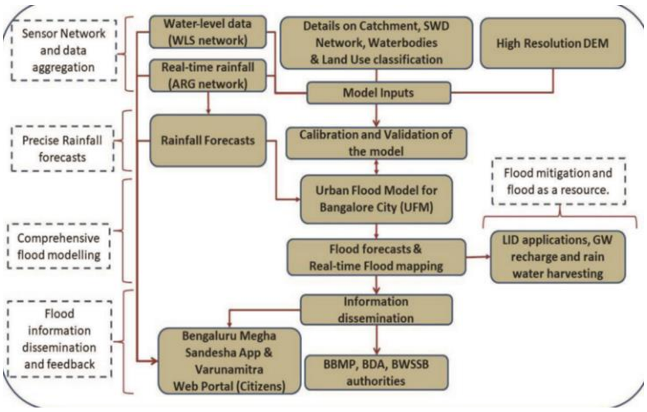
Establishment of sensor and rain gauge network and data aggregation.
Precise rainfall forecast system.
comprehensive flood modelling.
Flood information dissemination and feedback
Innovative technologies for flood mitigation and management
Documentation and packaging of flood management.

Figure 16 Flood Resilience Rose



Source - Author

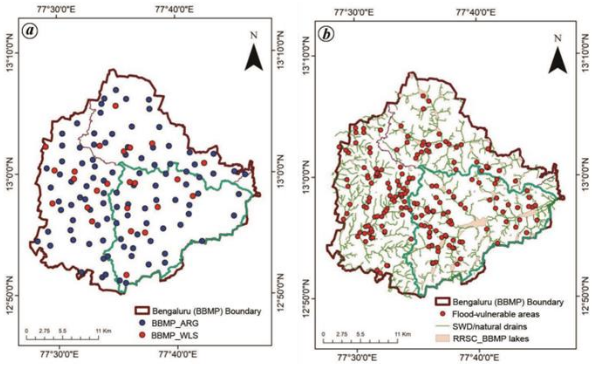
Figure 17 Components of IUFM



Source - IUFM Integrated urban flood management (2011)

One automatic rain gauge for every 7 sq. km. and 25 water-level sensors (WLS) have been installed with SIM throughout Bengaluru in order to monitor the flow during flood events. Based on the identified flood-vulnerable areas, telemetric WLSs have been installed on storm water drains (SWDs) at various significant locations. The digital elevation model (DEM) has been obtained by processing a contour map with a 1 m spatial resolution provided by BDA.

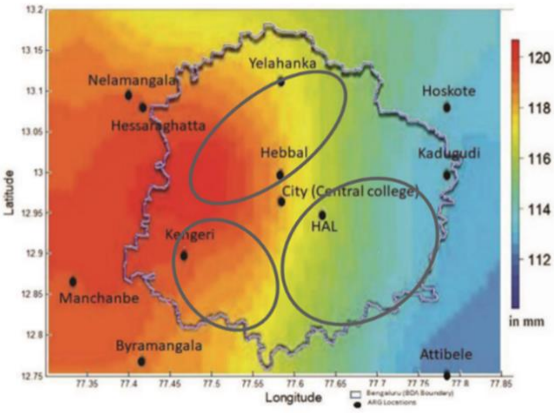
Figure 18 Location of ARW & WSM



Source - IUFM Integrated urban flood management (2011)

For each of the 100 ARG sites, the predictions were acquired for 12, 24, 36, 48, 60, and 72 hours every day at 12:30 pm. Using the SAC WRF model, the real-time datsa is shown five times a day between 5 and 7 am. This enables projections based on observable data to be more accurate.

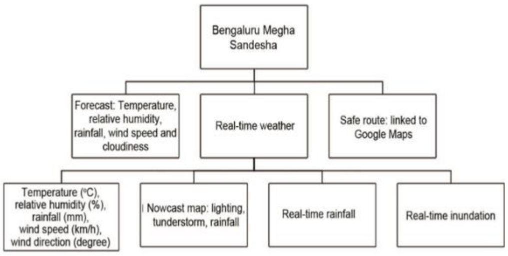
Figure 19 Areas of Maximum Precipitation



Source - IUFM Integrated urban flood management (2011)

Specifically created for urban areas, SWMM is a dynamic rainfall–run-off simulation model that is used to calculate run-off from rainfall after taking into consideration several system losses. After preprocessing, connecting, and importing from ArcGIS to SWMM, the nodes, drains, ARG sites, and sub-catchments were all included. The SWMM results are fed into the HEC-RAS model to produce maps of flood inundation.

Figure 20 Components of Megha Sandesha Flood Application

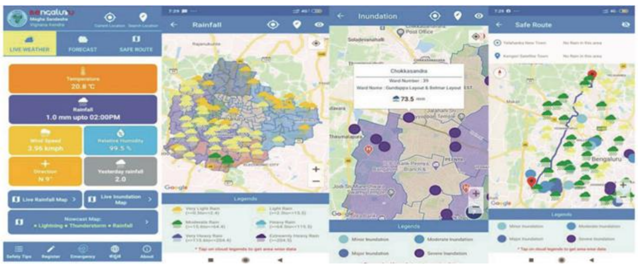


Source - IUFM Integrated urban flood management (2011)

Model Outcome in 3 Stages

- The rainfall and flood forecast warning system.
- The post-flood damage alert system.
- Bengaluru Megha Sandesha mobile application and Varuna Mitra dynamic web portal

Figure 21 Megha Sandesha Application Interface



Source - IUFM Integrated urban flood management (2011)

Varuna Mitra is a dedicated, dynamic web portal for weather information in the BBMP area. The information is based on real-time data from 100 ARGs and 12 AWSs installed by KSNDMC across Bengaluru. The urban flood model outcomes serve as an input to the flood inundation section and flood forecast section of the app.

- Glitch in the functioning of mobile app (Megha Sandesha).
- Improper maintenance of ARW & WLS.
- Exacerbation of LID innovative techniques such as Bio- swales, Retention ponds etc.
- Coordination gap between authorities like BWSSB, BBMP and BDA.
- Unregulated development without incorporating land use pattern.

Innovative technologies for flood mitigation and management

The urban flood model is also being extended to assess the possibility of reuse of flood water through innovative technologies, such as the use of low impact developments (LIDs). A few LID options include use of porous pavement technology and porous bed channels for groundwater recharge, and rainwater harvesting.

The packaging aims at providing streamlined solution with an efficient design for an integrated urban flood management practice. At present, it is a pilot project for integrated urban flood management solution in India. The model is being constantly improved incorporating changes in land-use pattern.

Findings

The main causes of urban flooding are well-known and include urbanization, excessive rainfall over cities and/or upstream catchments, overflows from upstream dams and rivers, and construction on flood plains or low-lying city districts. Urban heat islands are another element that has been connected to rising convective rainfall in and around cities and triggering floods. Rapid urbanization has resulted in fewer water bodies, less groundwater recharge, more paved areas, and smaller urban drainage systems. There has been a noticeable shift in rural-urban migration due to economic opportunities. The limited water and land resources that are found inside the city limits are therefore severely strained. A few Indian cities have implemented efforts to avert flooding. Among them are non-structural activities like automated Weather stations to track Rainfall.

Most of these studies on mapping flood plains modeled the flows in urban drainage systems using publicly available tools like SWMM, HEC-HMS, and HEC-RAS, or they utilized privately developed software. Even though these areas have been charted, it has been difficult to forbid new building in the flood zones and risky sites due to a lack of space and difficulty relocating the squatters. Even after being warned, the squatters won't go because they fear they won't be allowed to come back.

Conclusion and Recommendations

In many Indian cities, establishing flood resilience measures now requires considering hydrologic extremes, climate change, and growing urbanization. The real issue is maintaining regular access to water, whereas flooding is thought to be a monsoon-season occurrence. It is vital to maintain proper water levels in the dams for power generation, farmer irrigation, and municipal water supply to offer enough storage to lessen floods. The management of many sectoral development processes is significantly impacted by these processes. To design and carry out surface water management plans, the intricate relationship between development processes and flood risk needs a precise conceptual framework backed by the right institutional and organizational procedures. A multifaceted mitigation strategy would consider actions like stopping or limiting new land use practices within the basin; removing some structures from the floodway; flood-proofing structures within the flood plain; introducing structural measures like levees, dams, and constructed channels; implementing flood forecasting and warning systems connected to response mechanisms. or inappropriate development or activities in the flood plain. Even yet, a single disastrous flood has the power to stall a city's development for decades and turn away investors. Given increasing sea levels and heavier rainfall occurring at shorter intervals of time due to climate change, cities must promptly upgrade their drainage systems for increased intensity rainfalls and provide enough solutions if they wish to function efficiently during intense downpour. The government of India recently launched the massive AMRUT initiative, Atal Mission for Rejuvenation and Urban Transformation, JSA initiative, Jal Shakti Abhiyan and ASM, Amrit Sarovar mission, with an emphasis on providing water supply, sewage, stormwater drains, green spaces, and public transportation in 500 Indian cities. All of these tasks are under SDG-6 (Sanitation and Clean Water).

Additionally, climate resilience has come into focus is Goal No. 13. Better urban storm drainage system planning is made possible by the 2019 publication of the Manual on Storm Drainage, which provides planners with much-needed support in the design and implementation of sustainable and rainfall-based drainage systems. Conduct a comprehensive study of each identified areas to understand their DFVI, causes of flooding and Intervention techniques for urban flooding.

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